IP mobility mechanism for a packet radio network

Background of the invention

The invention relates to a mechanism for providing IP (Internet Protocol) mobility in a packet radio network such as GPRS or UMTS. IP mobility is the topic of standard RFC2002 by the Internet Engineering Task Force (IETF). This RFC standard is incorporated herein by reference. In short, IP mobility is a mechanism for providing a mobile user with telecommunications capability using an IP address. It enables mobile nodes to change their points of attachment in the Internet without changing their IP address. Thus it facilitates the communication of a mobile node and a correspondent node with the mobile node's home address. Fig. 1 illustrates the concept of an IP mobility mechanism in a packet radio network.

Within the context of this application, a 'Network Access Server (NAS)' is a device providing users with temporary, on-demand network access. This access is point-to-point using telephone, ISDN or cellular connections, etc. A 'Mobile Node (MN)' refers to a host that wishes to use a Home Network address while physically connected by a point-to-point link (phone line, ISDN, etc.) to a NAS that does not reside on the Home Network. A 'Correspondent node' is a peer node with which a mobile node is communicating. The correspondent node may be either mobile or stationary. A 'Mobile Station (MS)' is a mobile node having a radio interface to the network. A 'Tunnel' is the path followed by a datagram when encapsulated. The model of a tunnel is such that, while encapsulated, a datagram is routed to a known decapsulation agent, which decapsulates the datagram and then correctly delivers it to its ultimate destination. Each mobile node connecting to a home agent does so over a unique tunnel, identified by a tunnel identifier which is unique to a given Foreign Agent/Home Agent pair.

The MS can be a laptop computer PC connected to a packet radio-enabled cellular telephone. Alternatively, the MS can be an integrated combination of a small computer and a packet radio telephone, similar in appearance to the Nokia Communicator 9000 series. Yet further embodiments of the MS are various pagers, remote-control, surveillance and/or data-acquisition devices, etc.

The Radio Access Network RAN can be a part of a GPRS system or a third generation (3G) system, such as UMTS. The RAN comprises an air interface Um which is a performance bottleneck. SGSN and GGSN are GPRS

terms for access and gateway support nodes, respectively. In so-called third generation (3G) systems, the SGSN nodes are sometimes referred to as 3G-SGSN nodes. Subscriber information is stored permanently in the Home Location Register HLR.

A 'Home Network' is the address space of the network to which a user logically belongs. When a workstation is physically connected to a LAN, the LAN address space is the user's home network. A 'Home Address' is an address that is assigned to a mobile node for an extended period of time. It may remain unchanged regardless of where the MN is attached to the Internet. Alternatively, it could be assigned from a pool of addresses. A 'Home Agent' is a routing entity in a mobile node's home network which tunnels packets for delivery to the mobile node when it is away from home, and maintains current location information for the mobile node. It tunnels datagrams for delivery to, and detunnels datagrams from, a mobile node when the mobile node is away from home.

A 'Foreign Agent' refers to a routing entity on a mobile node's visited network which provides routing services to the mobile node while registered, thus allowing a mobile node to utilise its home network address. The foreign agent detunnels and delivers packets to the mobile node that were tunnelled by the mobile node's home agent. For datagrams sent by a mobile node, the foreign agent may serve as a default router for registered mobile nodes.

RFC2002 defines 'Care-of-Address' (COA) as the termination point of a tunnel toward a mobile node, for datagrams forwarded to the mobile node while it is away from home. The protocol can use two different types of care-of-address: a "foreign agent care-of-address" is an address of a foreign agent with which the mobile node is registered, and a "co-located care-of-address" is an externally obtained local address which the mobile node has associated with one of its own network interfaces. Within the context of this application, the 'Care-of Address' (COA) is an address of a foreign agent with which the mobile node is registered. An MN may have several COAs at the same time. A primary COA is the address which the MN sends to its HA when registering. The list of COAs is updated when advertisements are received by the mobile node. If an advertisement expires, its entry or entries should be deleted from the list. One foreign agent can provide more than one COA in its advertisements. 'Mobility Binding' is the association of a Home Address with a Foreign

Agent IP address and a Tunnel ID. An MN registers its COA with its HA by sending a Registration Request. The HA replies with a Registration Reply and retains a binding for the MN.

In basic versions of Mobile IP, all datagrams destined to an MN are routed via the MN's home network and home agent HA. This process is called triangle routing. It may increase the load of the network and the HA may be a performance bottleneck. So-called route optimization protocol extensions for Mobile IP aim to eliminate the problems associated with triangle routing. In route optimization, correspondent nodes and previous FAs may retain an up-to-date binding for the MN in their binding caches. As a result, the correspondent nodes may tunnel their datagrams directly to the MN's COA and previous FAs may forward datagrams destined to the MN to the MN's current COA. The binding may be retained after reception of a Binding Update. If requested, a node should acknowledge the reception by sending a Binding Acknowledge. These messages must be authenticated. They are typically carried by User Datagram Protocol (UDP).

Routing data packets to an MN is a problem in a packet radio network, such as the GPRS. This is because the data network address of the MN typically has a static routing mechanism, whereas a MN can roam from one subnetwork to another. One approach for data packet routing in a mobile environment is the concept of Mobile IP. Mobile IP enables the routing of IP datagrams to mobile hosts, independent of the point of attachment in the subnetwork.

The standard Mobile IP concept does not fit exactly into the GPRS environment because network protocols other than IP must be supported, too. The GPRS infrastructure comprises support nodes such as a GPRS gateway support node (GGSN) and a GPRS serving support node (SGSN). The main functions of the GGSN nodes involve interaction with the external data network. The GGSN updates the location directory using routing information supplied by the SGSNs about an MS's path and routes the external data network protocol packet encapsulated over the GPRS backbone to the SGSN currently serving the MS. It also decapsulates and forwards external data network packets to the appropriate data network and handles the billing of data traffic.

The main functions of the SGSN are to detect new GPRS mobile stations in its service area, handle the process of registering the new MSs

along with the GPRS registers, send/receive data packets to/from the GPRS MS, and keep a record of the location of the MSs inside of its service area. The subscription information is stored in a GPRS register where the mapping between a mobile's identity (such as MS-ISDN or IMSI) and the PSPDN address is stored. The HLR acts as a database from which the SGSNs can ask whether a new MS in its area is allowed to join the GPRS network.

The GPRS gateway support nodes GGSN connect an operator's GPRS network to external systems, such as other operators' GPRS systems, data networks 11, such as an IP network (Internet) or an X.25 network, and service centres. Fixed hosts 14 can be connected to the data network 11 e.g. by means of a local area network LAN and a router 15. A border gateway BG provides access to an inter-operator GPRS backbone network 12. The GGSN may also be connected directly to a private corporate network or a host. The GGSN includes GPRS subscribers' PDP addresses and routing information, i.e. SGSN addresses. Routing information is used for tunnelling protocol data units PDU from the data network 11 to the current switching point of the MS, i.e. to the serving SGSN. The functionalities of the SGSN and GGSN can be connected to the same physical node.

The home location register HLR of the GSM network contains GPRS subscriber data and routing information and it maps the subscriber's IMSI into one or more pairs of PDP type and PDP address. The HLR also maps each PDP type and PDP address pair into a GGSN node. The SGSN has a Gr interface to the HLR (a direct signalling connection or via an internal backbone network 13). The HLR of a roaming MS and its serving SGSN may be in different mobile communication networks.

The intra-operator backbone network 13, which interconnects an operator's SGSN and GGSN equipment can be implemented, for example by means of a local network, such as an IP network. It should be noted that an operator's GPRS network can also be implemented without the intra-operator backbone network, e.g. by providing all features in one computer.

A GPRS network in its current form is able to support IP mobility if a MS implements the Mobile IP protocol and if it has a private IP address assigned by some company or Internet service provider (ISP). When a GGSN node assigns a temporary IP address to the MS, the MS can use this temporary address as its care-of-address (COA) and register the address with its home agent, thus benefiting from the Mobile IP services. This is also true

when the MS is using a predefined GGSN IP address, which can also be regarded as a COA. The only entity that can prevent the MS from using the GGSN-assigned IP address as its COA is a foreign agent (FA) whose agent advertisement messages are received by the MS and which require the MS to register with that particular FA.

A problem of the known IP mobility mechanisms is poor integration with packet radio systems. In other words, the known IP mobility mechanisms are designed, at least primarily, for wired access systems. This is turn has the side effect that each datagram is processed though a large number of different protocol layers, which involves a large processing overhead. Also, equipping each datagram with a large number of protocol headers wastes the capacity of the network.

Disclosure of the invention

An object of the invention is to improve the integration between IP mobility mechanisms and packet radio systems. In other words, the invention should solve, or at least minimize, the problems associated with the prior art IP mobility mechanisms. The object is achieved with a method and equipment which are characterized by what is disclosed in the attached independent claims. Preferred embodiments of the invention are disclosed in the attached dependent claims.

The invention is based on the vision that a home agent HA is installed at the edge of the packet radio network. Such a location allows the HA to decide whether to route datagrams addressed to a mobile subscriber using GPRS/GTP or Internet/IP. Preferably, the HA is integrated or consolidated into a gateway support node of a packet radio network. In a GPRS network, suitable gateway support nodes are the GGSN nodes. Each connection has two PDP contexts in the GGSN. One context corresponds to the fixed IP address stored in the subscribers home-GGSN, and the other corresponds to a dynamic address stored in the visited GGSN. In terms of mobility management (MM), the invention enables the use of two coexisting MM contexts, a GPRS MM context and a Mobile IP context. The integration of the home agent to the subscriber's home GGSN decides which MM context should be used for routing a datagram.

A further advantage of the invention is that Mobile IP support becomes a service provided by the network operator. Thus the operator can also charge the users for this service.

According to a preferred embodiment of the invention, the protocol stack used for routing data packets (i.e. datagrams) at the integrated gateway node/home agent is streamlined by routing data packets directly using network layer (i.e. layer 3) protocols. This embodiment results in increased throughput and/or lighter overhead due to a smaller protocol stack at the integrated gateway node/home agent, when routing IP datagrams.

According to another preferred embodiment of the invention, foreign agents FA are installed in SGSN nodes. Such placement of foreign agents maximizes the benefits of the invention, since it maximizes the span of the network that can be covered with the smaller protocol stack. (Currently, the IP tunnel ends at the SGSN. If the IP tunnel is extended into the Radio Access Network RAN, then, preferably, the foreign agents FA should also be moved to the RAN. In such a case, a possible network element could be the BSC/RNC.)

Alternatively, the FAs can be installed at the GGSN but then a GTP tunnel is required for routing IP packets between the GGSN and the SGSN. As a yet further alternative, the FAs can be omitted altogether, if IPv6 and a technique known as address autoconfiguration is used.

Brief description of the drawings

The invention will be described in more detail by means of preferred embodiments with reference to the appended drawing on which:

Fig. 1 illustrates an IP mobility mechanism comprising a known home agent HA and routing of datagrams at the HA; and

Fig. 2 illustrates an IP mobility mechanism comprising a home agent HA according to the invention and routing of datagrams at the HA.

Detailed description of the invention

Fig. 1 is block diagram illustrating an IP mobility mechanism comprising a home agent HA located in the internal backbone network 13. (Such a location is shown only as an example.) Reference numeral 18 in the lower-left hand corner of Fig. 1 denotes a protocol stack at such a prior art HA. The double-headed arrow illustrates routing of IP datagrams at the GGSN. Correspondingly, reference numeral 19 denotes a datagram comprising a payload portion PL and a number of headers H, one header for each of the protocols needed for routing the datagram. It is apparent that processing each datagram though a large number of protocol layers involves a large processing over-

head. Also, equipping each datagram with a large number of protocol headers wastes network capacity.

Fig. 2 illustrates an IP mobility mechanism comprising a home agent HA according to the invention, whereby the home agent HA is integrated into a GGSN node, commonly referred to as a gateway node. Reference numeral 20 denotes a protocol stack at the HA according to the invention. Correspondingly, reference numeral 21 denotes a datagram according to the invention. The datagram comprises a payload portion PL and one header H for each of the protocols needed for routing the datagram. It is apparent that the invention saves processing overhead and increases the throughput by decreasing the number of headers required in the datagrams.

If IPv4 is used, the HA intercepts datagrams addressed to the mobile station MS, encapsulates them and sends them to the MS's COA. The COA may be provided by a foreign agent FA, or it may be acquired by the MS itself using a technique such as the DHCP (Dynamic Host Configuration Protocol).

In known IP mobility mechanisms, foreign agents FA are typically installed as software routines in the mobile nodes MN. Fig. 1 shows an embodiment wherein foreign agents FA are installed in every SGSN node. (Such FA placement is the subject matter of Reference 1.) Each FA has an IP address in the Internet and in the operator's own private GPRS/3G network. For each SGSN/FA, a permanent packet data context exists in the corresponding gateway node GGSN to enable tunnelling towards the FA. One of the link protocols between an MS and the SGSN (e.g. Layer 3 Mobility Management, L3-MM) is modified to support IP mobility.

According to an alternative embodiment shown in reference 1, the foreign agent FA is integrated into a gateway node GGSN. In this case the MS uses as its COA the address of the FA in the gateway node. In order to establish mobility binding, the MS has to send additional information to the SGSN. Because of this additional information, the selected gateway node knows that a received IP address is valid although it does not belong to this particular gateway node. The gateway node detects registration messages from the MS and sends them to its FA unit for processing. This can be implemented easily if the gateway node's router unit sends all packets with a time-to-live field of zero to the FA. The advantage of this feature is that the gateway node does not have to study incoming packets in any great detail which would require

large amounts of processing power. Moreover, the gateway node GGSN/PDAN can accept any IP address from the MS and use the address of the FA as the MS's COA.

As a yet further alternative, the FAs can be dispensed with altogether, if IPv6 and a technique known as address autoconfiguration is used. The mobility support in IPv6 combines the concepts of Mobile IP and route optimization. Each time the MN moves its point of attachment from one IP subnetwork to another, it needs a COA from the current subnetwork. The MN may configure the COA by stateful or stateless autoconfiguration. (Stateful autoconfiguration relies on an address configuration server; in stateless autoconfiguration the MN picks an address and tries to find out if this address is already in use.)

The MN may send Binding Update messages, or 'options' to its correspondent nodes to let them dynamically learn and cache the MN's binding. Using the binding, the correspondent nodes may send their packets directly to the MN's COA. ('Option' is a term used in connection with IPv6 for certain optional headers inserted after the IPv6 header. Similarly, with IPv6, the word 'packet' is generally used for datagrams.) The Binding Update/Acknowledge Options are carried as IPv6 Destination Options and they may be included in any IPv6 packet. Destination Options are examined only by the packet's destination node, whereby the load of the intervening routers is not increased.

When sending a packet, a Correspondent Node checks its binding cache for an entry for the packet's destination address. If an entry is found, the Correspondent Node routes the packet directly to the MN's COA. An IPv6 Routing Header is used instead of IPv6 encapsulation. The Routing Header includes the MN's Home Address. If no entry is found, the Correspondent Node sends the packet normally to the MN's Home Network, wherein the HA intercepts the packet and tunnels it to the MN's COA using IPv6 encapsulation.

The description only illustrates preferred embodiments of the invention. The invention is not, however, limited to these examples or the terms used, but it may vary within the scope of the appended claims.

Reference

1. Finnish patent application [agent's reference 2980379FI], assigned and titled similarly and filed on the same day as the present application.